Butler University Botanical Studies
I ***Papers No. 2 and 3***

Some Ecological Factors in Secondary Succession: Upland Hardwood

II. Soil Reaction and Plant Distribution in the Sycamore Creek Region

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The Genus Trillium in Indiana

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SOME ECOLOGICAL FACTORS IN SECONDARY SUCCESSION: UPLAND HARDWOODS

II. SOIL REACTION AND PLANT DISTRIBUTION IN THE SYCAMORE CREEK REGION

By Stanley A. Cain *and* Ray C. Friesner

An examination of the vegetation of the Sycamore Creek region would certainly warrant the assumption that the soils of many of the ridge tops are decidedly acid, for there are a number of plant communities made up of notoriously acid-tolerant species. Conspicuous members of these communities are *Vaccinium vacillans*[1], *V. stamineum, Gaylussacia baccata, Populus grandidentata,* and various mosses, as *Polytrichum juniperinum, Catherinea angustata, Leucobryum, Dicranum,* etc. Since these communities are exclusively on the tops and upper slopes of the characteristically narrow ridges, it was thought desirable to investigate the extent of the hydrogen-ion concentration of these soils and to ascertain any relations existing between the pH and the topography, and, inevitably, of course, the vegetation.

The existence of a correlation between the reaction of the substratum and the nature of the plant cover was suggested by Pfeffer in the last part of last century; but it was not until the technique of soil reaction determination was worked out, about 1915-16, that any activity was seen along this line. Since that time there has appeared a voluminous literature. It is not within the scope of this paper to go into the principles underlying the technique, Clark (7), or the purpose of such investigations, Christopherson (6). It will be sufficient to note a few facts which have stimulated the present studies.

First, Salisbury (11) in 1922, published on the stratification of hydrogen-ion concentration of the soil in relation to leaching and plant succession. He came to the conclusion that, due to leaching action, the surface soil is poorest in bases which increase in amount with increasing depth. The organic content decreases rapidly with increasing depth, associated with which there is a gradient of hydrogen-ion concentration attaining its maximum at the surface. The view is advanced that woodlands in general and probably all types of undisturbed plant communities are tending to become progressively more acid, with consequent changes in the character of the vegetation. This he summarizes in two fundamental principles, viz.:

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[1] Nomenclature: Gray's New Manual of Botany, 7th Ed.

(a) A progressive increase in the acidity, resulting in corresponding changes in the character of the vegetation;

(b) A more rapid leaching on high than on low ground, resulting in a depression of the upper limits of the zones as the summit vegetation extends with the extension of higher acidity.

Second, when the formations are not too poor in species, we can, according to Olsen (10), conclude from the composition of the vegetation to the hydrogen-ion concentration of the soil.

Lastly, this problem was made desirable because of an idea derived from a paper by Miss Braun (1) on certain relic colonies in southern Ohio. The plant communities considered by her were prairie relics. It was thought that the Sycamore Creek communities here considered are also relic colonies, but in this case xerophytic-acid-boreal relics. Bog-plant communities along the southern limits of their present distribution are well-known hydrophytic-acid-boreal relics. Transeau (12); Cain (3). It is believed that the xerophytic communities are much more common, although not so well known. Topography and stream erosion are conducive to the development and maintenance of these xerophytic relics, whereas the process of plantation tends toward the elimination of bog-plant habitats.

Procedure—Three ridges were selected for the present investigation. In the case of series AB and series C, the ridges present north and south slopes, the crest of the ridge being about one hundred feet above the base. Series D represents a continuation of C to the northward, but runs up onto ridge D lengthwise. The symbols A, B, C, D, correspond to the atmometer stations. Cain and Friesner (4). Station A was on the north slope and Station B was on the top of the ridge here indicated as AB. Atmometer Station C was on the top of the ridge where the pH series C was located. Series D was an extension of line C in the direction of Station D, but was not actually to its location. The direction of the line for each series was selected and then run out by the use of a surveyor's tape and an Abney clinometer. Notes were kept of the angles and the length of each slope, so that it was an easy matter to indicate the location of the samples and plot the topography of the ridges in the graphs.

Soil samples of about two hundred grams each were collected in paper bags. Those samples indicated as surface soil were taken immediately beneath the litter in the soil layer of highest organic content. Subsoil samples were taken at a depth of approximately six inches, which was sufficient to pass the humus layer in all cases. In series AB, samples 30 and 32 were taken at three inches depth, which was the bottom of the soil due to the sandstone outcropping. As indicated in the tables, these samples were in pairs, surface and subsoils taken in a vertical line.

The hydrogen-ion concentration of these samples was determined electrometrically by the use of the Youden portable apparatus developed at the Boyce Thompson Institute, 1928. All readings were completed within a few days after collecting. The samples were procured on November 10 and November 16. Gustafson (9) has shown that soil samples do not undergo any appreciable change on storage. Three or more separate readings were made from each sample collected. The present data include about 250 readings for the establishment of three curves.

Results and Discussion—From an examination of the tables and curves for the three series of pH readings, it will be seen that there is a general tendency for the subsoil to be more acid than the surface soil. Of the forty-one sets of surface and subsoil samples, only seven showed the surface to be more acid than the subsoil. These seven instances were:

Sample No.	Surface Soil pH	Subsoil pH
AB 1	4.756	4.926
7	4.196	4.569
13	5.286	5.789
C 9	5.891	6.474
D 11	4.903	5.596
13	5.027	5.136
15	5.212	5.636

It will be seen that these samples are among the more acid. On referring them to their topographical positions, one finds that these samples were taken on the ridge tops except for AB 13 and C 9, which were on lower slopes. These surface soils contain very little organic matter, the humus having been greatly reduced, apparently by fire. The differences in pH between the surface and the subsoils in some cases are of about the same order as the differences between different tests of the same sample, but in most cases there is a much greater difference between the averages for surface and subsoil than between different tests of the same sample. It should be noted that the former occur mainly in samples which are of the more acid type for this region.

In view of these results, it must be concluded that the stratification of soil reaction in this region results in a gradient reaching a maximum pH in the subsoil. This result is directly opposed to part of the conclusion reached by Salisbury (11), which he states as follows: "The organic content decreases rapidly with increasing depth, associated with which, and in some cases with increasing base content, there is a gradient of hydrogen-ion concentration attaining its maximum at the surface." In some previous work, Cain (2), the type of gradient observed by Salisbury was found to exist for lowland forest soils and probably will be found in some upland soils of this region when a more extensive study is made. A number of soil reaction profiles and transects of high ridges and mountains in the Great Smoky mountains of Tennessee indicate gradients entirely in harmony with Salisbury's observations, where, despite a naturally acid subsoil, the surface soils reach extreme hydrogen-ion concentrations as a result of upland peat formation, Cain (5).

The conclusion reached by Salisbury is an entirely reasonable one. The inversion of the gradient in the soils of the Sycamore Creek region is probably explained by the following facts. The vegetation of these ridges has been greatly disturbed by cutting and fires, resulting in a reduction of the organic content of the surface soils. Second, the underlying sandstone and shale rocks, upon decomposition, produce an inorganic acid soil. Christopherson (6) and others have noticed that the composition of the parent rock influences the hydrogen-ion concentration of the soils, granites and amphibolites producing soils of high acidity, while schists produce soils near the neutral point.

The Wisconsin ice sheet covered that part of Morgan county here under study. The hills are topped with a heavy clay known as the Miami Clay Loam, which is probably of this glacial origin, though in many places it is very difficult to be certain that it is not residual soil from the underlying sandstone (knobstone) and shale. This clay varies from zero to several feet in thickness. Where the clay is absent, such as on the slopes, the soil is very shallow and is clearly the residual product of underlying sandy shale which in turn seems to be but local shaleimpurities of the knobstone. Reaction studies of these soils seem to indicate no correlation between soil reaction and relative amounts of sand, shale and clay in any particular soil sample.

TABLE I—pH OF SOIL SAMPLES, RIDGE TRANSECT AB, SYCAMORE CREEK

SURFACE SOIL			SUBSOIL			SURFACE SOIL			SUBSOIL		
No.	pH	Aver.	No.	pH	Aver.	No.	pH	Aver.	No.	pH	Aver.
1a	4.796		2a	4.893		3a	5.398		4a	5.000	
1b	4.779	4.756	2b	4.949	4.926	3b	5.483	5.379	4b	4.915	4.938
1c	4.694		2c	4.847		3c	5.255		4c	4.898	
5a	4.983		6a	4.592		7a	4.235		8a	4.541	
5b	4.813	4.853	6b	4.558	4.575	7b	4.320	4.196	8b	4.541	4.569
5c	4.762		6c	4.575		7c	4.033		8c	4.626	
9a	4.507		10a	4.439		11a	5.034		12a	4.694	
9b	4.711	4.575	10b	4.405	4.442	11b	4.813	5.051	12b	4.626	4.660
9c	4.507		10c	4.483		11c	5.306		12c	4.660	
13a	5.170		14a	5.704		15a	6.180		16a	6.486	
13b	5.272	5.286	14b	5.925	5.789	15b	6.367	6.378	16b	6.486	6.356
13c	5.415		14c	5.738		15c	6.588		16c	6.095	
17a	7.285		18a	7.530		19a	7.530		20a	7.506	
17b	7.666	7.566	18b	7.598	7.528	19b	7.770	7.690	20b	7.353	7.432
17c	7.717		18c	7.455		19c	7.770		20c	7.438	
21a	6.469		22a	5.085		23a	6.367		24a	5.755	
21b	6.741	6.560	22b	4.830	4.955	23b	6.299	6.367	24b	5.670	5.721
21c	6.469		22c	4.949		23c	6.435		24c	5.738	
25a	5.272		26a	4.745		27a	4.898		28a	4.728	
25b	5.119	5.315	26b	4.762	4.773	27b	4.983	4.955	28b	4.864	4.853
25c	5.255		26c	4.813		27c	4.983		28c	4.966	
29a	5.857		30a	5.153		31a	5.636		32a	5.069	
29b	5.925	5.857	30b	5.017	5.096	31b	5.676	5.647	32b	5.085	5.074
29c	5.789		30c	5.119		31c	5.636		32c	5.068	
33a	6.452		34a	4.609		35a	6.333		36a	5.102	
33b	6.452	6.486	34b	4.643	4.654	35b	6.486	6.435	36b	5.051	5.051
33c	6.554		34c	4.711		35c	6.486		36c	5.000	
37a	6.435		38a	5.670		39a	6.486		40a	5.187	
37b	6.707	6.323	38b	5.318	5.447	39b	6.588	6.418	40b	5.238	5.227
37c	6.826		38c	5.289		39c	6.180		40c	5.255	

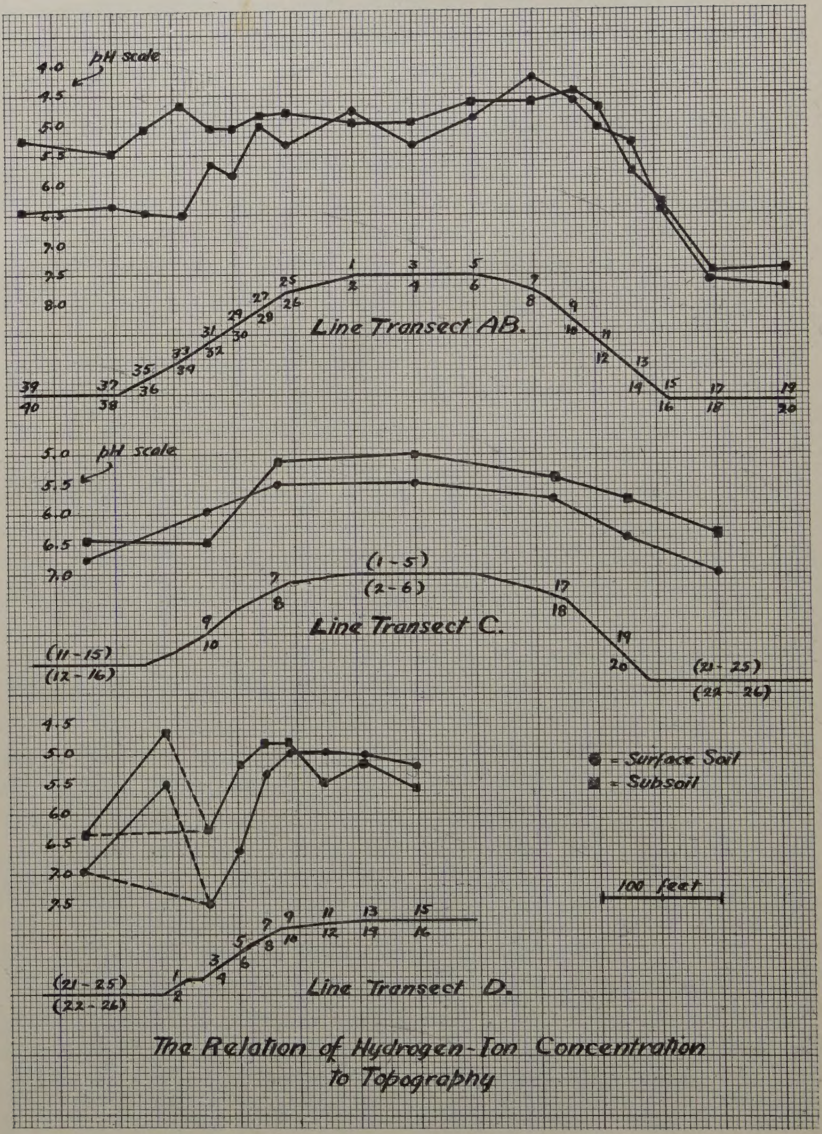

Figure 1. The relation of hydrogen-ion concentration to topography Series AB, C, D

TABLE II—pH OF SOIL SAMPLES, RIDGE TRANSECT C, SYCAMORE CREEK

SURFACE SOIL			SUBSOIL			SURFACE SOIL			SUBSOIL		
No.	pH	Aver.	No.	pH	Aver.	No.	pH	Aver.	No.	pH	Aver.
1a	5.772		2a	5.170		3a	4.983		4a	4.949	
1b	5.721	5.743	2b	5.187	5.204	3b	5.085	5.218	4b	4.966	4.972
1c	5.738		2c	5.255		3c	5.585		4c	5.000	
5a	5.432		6a	4.864		7a	5.381		8a	4.949	
5b	5.398	5.485	6b	4.762	4.830	7b	5.364	5.495	8b	5.136	5.113
5c	5.534		6c	4.864		7c	5.466		8c	5.255	
						7d	5.772				
9a	5.602		10a	6.537		11a	6.945		12a	6.520	
9b	5.959	5.891	10b	6.537	6.474	11b	6.401	6.764	12b	6.520	6.560
9c	6.112		10c	6.350		11c	6.945		12c	6.639	
13a	6.707		14a	6.265		15a	6.571		16a	6.588	
13b	7.030	6.888	14b	6.265	6.146	15b	6.826	6.718	16b	6.656	6.599
13c	6.928		14c	5.908		15c	6.758		16c	6.554	
17a	5.755		18a	5.415		19a	6.435		20a	5.974	
17b	5.721	5.749	18b	5.449	5.432	19b	6.367	6.401	20b	5.636	5.778
17c	5.772		18c	5.432		19c	6.401		20c	5.832	
21a	6.571		22a	5.942		23a	6.637		24a	6.214	
21b	6.775	6.707	22b	5.806	5.840	23b	7.047	6.911	24b	6.248	6.288
21c	6.775		22c	5.772		23c	7.013		24c	6.410	
25a	7.183		26a	7.047							
25b	7.370	7.308	26b	6.860	6.951						
25c	7.370		26c	6.945							

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TABLE III—pH OF SOIL SAMPLES, RIDGE TRANSECT D, SYCAMORE CREEK

SURFACE SOIL			SUBSOIL			SURFACE SOIL			SUBSOIL		
No.	pH	Aver.	No.	pH	Aver.	No.	pH	Aver.	No.	pH	Aver.
1a	5.670		2a	4.864		3a	7.564		4a	6.282	
1b	5.449	5.551	2b	4.422	4.626	3b	7.387	7.539	4b	6.044	6.203
1c	5.534		2c	4.592		3c	7.666		4c	6.282	
5a	6.911		6a	5.344		7a	5.415		8a	4.864	
5b	6.350	6.639	6b	5.000	5.115	7b	5.221	5.314	8b	4.864	4.869
5c	6.656		6c	5.000		7c	5.306		8c	4.881	
9a	4.830		10a	4.881		11a	4.966		12a	5.653	
9b	4.966	4.920	10b	4.830	4.852	11b	4.915	4.903	12b	5.806	5.596
9c	4.966		10c	4.874		11c	4.830		12c	5.330	
13a	5.221		14a	5.136		15a	5.068		16a	5.704	
13b	5.204	5.027	14b	5.272	5.136	15b	5.330	5.212	16b	5.806	5.636
13c	4.864		14c	5.000		15c	5.238		16c	5.398	
13d	4.847										

The soils of the Sycamore Creek region, from these observations, are found to range from pH 4.0 in series AB, sample 7, to pH 7.77 in sample 19 of that same series. By far the majority of the samples are acid in reaction. The most acid soils are characteristic of the ridge tops and upper slopes, while the soils of the bottoms are much less acid, many of them, in fact, being circumneutral. It can be seen from plotting the pH with the contour of the ridges that there is a general agreement of the three curves; that is, the line of the topography and the curves of the surface soil pH and the subsoil pH, plotted in continuous lines as they were collected, show conformity (Figure 1).

As has previously been mentioned, Salisbury noticed that "woodlands occupying valley slopes tend to exhibit less marked surface leaching as we descend, and the chief differences between upland and lowland woods are regarded as related to this factor." The present work is in complete agreement with that conclusion in so far as it expresses the relation of hydrogen-ion concentration to topography. There is sufficient evidence of the effect of more extensive leaching out of bases on the ridge tops and upper slopes. However, it is not believed that the conclusion is warranted that this difference in soil reaction constitutes the chief cause of the differences between upland and lowland vegetation. It must be remembered that, although soil reaction is an important factor, there are other factors, edaphic and climatic, contributing to the upland-lowland differences in vegetation. For example, differences in soil moisture and the physical and chemical nature of the soil (other than pH) are frequently important. Then there are the atmospheric factors summed up in the evaporating power of the air. Fuller (8) has shown that the differences in ratios between evaporation and growth-water in various plant associations are sufficient to be efficient factors in causing succession. Further, it must be noted that considerable fluctuations occur within different vegetation types, so that soil reaction becomes a factor capable of interpretation only in cases of considerable differences in the respective pH ranges of related plant associations. It is not desired, then, to deny soil reaction as a factor, but merely to emphasize the following points: (a) soil reaction alone is probably not often a limiting factor; (b) it is possible to determine soil reaction to a much finer degree than it can be interpreted in terms of vegetation. Therefore, the pH of plant associations should be expressed in terms of comparative ranges and averages of reaction. This is particularly desirable in view of local variations which occur in the soil reaction. Christopherson (6) comments on this point as follows: "Variation in the soil reaction may take place from one locality to another within short distances. The soil of one particular stand may thus vary considerably from place to place, and the soil of different stands of the same association may vary still more. In spite of this, however, the associations may be limited to a relatively narrow range of soil reactions, which are characteristic for each association."

TABLE IV—COMPARISON OF SOILS FROM RIDGES AB, C AND D

SURFACE SOIL			SUBSOIL		
SERIES AB					
Ridge top	pH 5.583	15 tests	Ridge top	pH 5.023	15 tests
Upper slope	pH 4.979	15 tests	Upper slope	pH 4.746	15 tests
Lower slope	pH 5.880	18 tests	Lower slope	pH 5.264	18 tests
Bottom	pH 6.996	12 tests	Bottom	pH 6.408	12 tests
SERIES C					
Ridge top	pH 5.473	9 tests	Ridge top	pH 5.002	9 tests
Upper slope	pH 5.622	7 tests	Upper slope	pH 5.272	6 tests
Lower slope	pH 6.146	6 tests	Lower slope	pH 6.126	6 tests
Bottom	pH 6.882	18 tests	Bottom	pH 6.347	18 tests
SERIES D					
Ridge top	pH 5.044	10 tests	Ridge top	pH 5.589	9 tests
Upper slope	pH 5.624	9 tests	Upper slope	pH 5.945	9 tests
Lower slope	pH 6.545	6 tests	Lower slope	pH 5.414	6 tests
Bottom	same as C		Bottom	same as C	
AVERAGES					
Ridge top	pH 5.366	34 tests	Ridge top	pH 5.122	33 tests
Upper slope	pH 5.408	31 tests	Upper slope	pH 4.988	30 tests
Lower slope	pH 6.190	30 tests	Lower slope	pH 5.601	30 tests
Bottom	pH 6.939	30 tests	Bottom	pH 6.377	30 tests
		125			123

Table IV sums up the results of the relation of soil reaction to topography, while the relation of the reaction to the vegetation is found to be as follows: The ridge tops and upper slopes are the location of the xerophytic-acid-boreal relics. It can therefore be said that these colonies are to be found in the Sycamore Creek region where the soil reaction averages around pH 5.3 to 5.4 for the surface and pH 4.9 to 5.1 for the subsoil. The relation of the various plant associations characteristic of the secondary succession in this region, to the soil reaction, is not fully investigated, but it would seem that all the stages are capable of development within the region. So, the climax beech-maple association is to be expected, even on the ridge tops. As a matter of fact, the ridge top in series D, although now open and occupied by *Vaccinium* and the like, bears remnants of a former climax forest. Two possible explanations occur for the presence of the ericads as a characteristic part of the early stages in secondary succession after cut-over and fire. First, they get a start after deforestation from seeds brought in by migrating birds. This has been shown by Darwin, Wallace, and many since their time, to be a common means of wide distribution for plants with edible fruits. The other possibility is that some of these plants have survived in the less favorable habitats (where competition is less severe) since early postglacial times, and are to be considered then as true boreal relics. It would not seem possible to determine at the present time which is the true explanation.

One or two facts remain to be pointed out as to differences in soil reactions. In the first place, the differences between the pH averages of the surface and the subsoil (Table IV) are greater at the bottom than they are at the top of the ridges; viz:

Ridge top—Average difference	.244
Upper slope—Average difference	.420
Lower slope—Average difference	.489
Bottom—Average difference	.449

TABLE V—SOIL REACTION DIFFERENCES, THREE TESTS PER SAMPLE, BASED ON 250 READINGS

Surface soil—	Greatest difference	.602
	Least difference	.040
	Average difference	.264
Subsoil—	Greatest difference	.442
	Least difference	.017
	Average difference	.236
ph 4 Range—	Average difference	.125
pH 6-7 Range—	Average difference	.288

Second, the tables reveal something of the amount of fluctuation to be expected in the soil reaction of different parts of the same locality. Table V brings out these points. The average deviation, based on three tests per sample, is .264 for the surface soils and slightly less, .236, for the subsoils. It will also be seen that the more acid the soil the less the fluctuations are likely to be, since the soils within the range of pH 4 show an average deviation of .125, while the circumneutral soils show a deviation of .288 in pH.

SUMMARY

1. Floristic studies of the ridges of the Sycamore Creek region reveal the presence of a number of acid-tolerant plants which make up xerophytic-acid-boreal relic colonies.
2. Soil reaction studies indicate that the soils in which these plants grow are decidedly acid, reaching a maximum on the ridge tops where the relic colonies are more abundant.
3. Hydrogen-ion curves parallel profile curves of the ridges, the former ascending with the latter.
4. The subsoil is more acid than the surface soil in most places, though a few samples were taken in which the reverse was true.

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THE GENUS TRILLIUM IN INDIANA

By Ray C. Friesner

The fact that members of the genus Trillium are quite variable is well borne out when one notes the number of reports of variations and teratological conditions in the literature. Such conditions make it important that more detailed critical study be made of members of the genus from the standpoint of their distribution and variation in smaller areas. Studies of the species occurring in wider areas were made by Gleason (19) and Gates (18). More detailed study of particular species in more restricted areas is of considerable value in adding light to the problem of species relationship and delimitation. Such a study was made for North and South Carolina by Peattie (26). The present paper is a similar attempt for the State of Indiana.

The following species, varieties, and forms occur in Indiana:

T. sessile L. (1).
T. sessile forma *luteum* Peattie (1a).
T. recurvatum Beck. (2).
T. recurvatum forma *luteum* n. f. (2a).
T. erectum L.* (3).
T. erectum var. *album* (Michx.) Pursh.* (3a).
T. grandiflorum (Michx.) Salisb. (4).
T. cernuum L. (5).
T. cernuum var. *macranthum* Eames and Wiegand (5a).
T. declinatum (Gray) Gleason.* (6).
T. declinatum forma *Walpolei* (Farwell) n. comb.* (6a).
T. nivale Riddell (7).

KEY TO TRILLIUMS OF INDIANA

1. Flowers sessile 2
1. Flowers peduncled 5
    2. Leaves sessile, petals not clawed 3
    2. Leaves petioled, petals clawed 4

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*It will be shown further on in this paper that *T. erectum* and *T. declinatum* should be considered as one species.

3. Petals red-brown .... sessile (1)
3. Petals greenish-yellow .... sessile luteum (1a)
    4. Petals red-brown .... recurvatum (2)
    4. Petals yellow to yellowish-green .... recurvatum luteum (2a)
5. Leaves sessile or subsessile, ovary six-angled 6
5. Leaves petioled, ovary three-angled .... nivale (7)
    6. Petals oblanceolate to obovate 7
    6. Petals lanceolate to ovate 8
7. Petals large, 20-50 mm at widest part .... grandiflorum (4)
7. Petals small, 10-17 mm at widest part .... cernuum macranthum (5a)
    8. Fresh flowers emitting marked "wet-dog" odor 9
    8. Fresh flowers not emitting such odor 10
9. Petals red-brown .... erectum (3)
9. Petals white .... erectum album (3a)
    10. Filaments 0.1-0.5 the length of anthers 11
    10. Filaments 0.6-1.2 the lengths of anthers 12
11. Petals white .... declinatum (6)
11. Petals red-brown or intermediate .... declinatum Walpolei (6a)
    12. Petals widest below the middle .... cernuum (5)
    12. Petals widest at or above middle .. cernuum macranthum (5a)

1. T. SESSILE L.

This species apparently occurs throughout the entire state. It has been reported in published lists (4, 9, 14, 29, 30) from twenty-two counties, and specimens in herbaria show it from thirty-three additional counties, making a total of fifty-five out of the ninety-eight counties. These counties are so well scattered over the state that there is little doubt that it occurs in every county. The species is subject to considerable teratological variation, Morris (24, 25); Hopkins (22); and Andrews (1, 2, 3). A petioled form was noted in the collection from Wabash College and completely pentamerous forms are in the herbaria of Indiana University and Butler University.

1a. T. SESSILE L. FORMA LUTEUM PEATTIE.
T. SESSILE VIRIDIFLORUM BEYER.

This is a form of *T. sessile* with green or greenish-yellow petals. There is no previous published record for the state. A very limited distribution is shown in the herbaria, but this is very likely due merely to the fact that collectors have failed to take it when in reality it is practically coexistent with the red-brown forms. This form should not be confused with *T. viride* Beck. which is a southern species which does not come into the state. The latter is like *T. sessile* in that it has sessile leaves, like *T. recurvatum* in that its petals (green) are clawed, but unlike both of them in that the stem is pubescent. The form *luteum* is similar to the species except for the green color of its petals. Occasional intermediates are found with petals streaked with red-brown, Beyer (5).

Beyer (5) has given the name, *T. sessile* forma *viridiflorum,* to specimens of the same character from West Virginia. His specimens have not been examined, but it is inferred from his description that the form is similar to that above named by Peattie (26). Since Peattie's paper antedated by four months the paper by Beyer, Beyer's name is considered a synonym of the name given by Peattie.

2. T. RECURVATUM BECK.

This species probably occurs in every county within the state. It is reported in published lists (7, 9, 14, 23, 29, 30) from twenty-five counties, and specimens in herbaria show it from forty-six additional counties. Distribution of this species in the state is practically identical with that of *T. sessile,* but it probably does not extend across the Appalachians to the seaboard states as does *T. sessile.* It is probable that this species represents the present-day end of a line of development going back to a "sessile-ancestor." Along this same line of development it is likely that the southern form, *T. viride* Beck., stands in an intermediate position. All three of these species have sessile flowers; *T. sessile* and *T. viride* have sessile leaves, and *T. recurvatum* has petioled leaves; while *T. recurvatum* and *T. viride* have clawed petals, and *T. sessile* has sessile petals. The northern limits of *T. viride* slightly overlap the southern limits of *T. recurvatum,* while *T. sessile* occurs throughout the range of both. This species is also subject to considerable teratological variation, Andrews (3).

2a. T. RECURVATUM FORMA LUTEUM N. F.

This form is based upon specimens collected near Bloomington, Indiana, and now in the herbaria of Indiana University and Butler University. The first specimens were collected by Dr. VanHook, of Indiana University, and later the writer visited the same locality and collected specimens which were deposited in the herbarium of Butler University.

The form differs from the species only in that the petals are lemon-yellow to greenish-yellow, instead of the usual red-brown. This form should not be confused with pathologic specimens of the species which have lost their normal red-brown color.

3. T. ERECTUM L.

This species, as defined in the manuals, does not seem to have a very wide distribution within the state. It is listed in published reports (8, 9, 12, 15) for twenty-three counties and herbarium specimens were found for five additional counties. There is good reason to believe that a number of the reports of *T. erectum* should be assigned to the *T. declinatum* as defined in the manuals. The majority of the specimens labelled *T. erectum* in the herbaria of the state are the white-petalled form.

It is extremely difficult to distinguish *T. erectum* from *T. declinatum* as they are defined in the manuals, and it is maintained by the writer that the two are but one species. It is shown in a subsequent paragraph that the only difference used by the authors for differentiating the two, to which there is no exception on the basis of Indiana specimens, is the odor which they emit when fresh.

3a. T. ERECTUM VAR. ALBUM (MICHX.) PURSH.

This variety is not mentioned as such in any previous published report for the state, though it is probably more common than the species. Gates (18) says that this variety "occurs sporadically and occasionally throughout the range of the species." The Indiana material of the species certainly belongs primarily to the variety, though the petals are pure white and do not show the yellowish-white of the eastern specimens of the variety. Since the odor of the fresh flowers is the only reliable method of distinguishing this form from *T. declinatum,* there is doubt whether any of the specimens to be found in the herbaria and labelled *T. erectum* are really *T. erectum* or whether they are *T. declinatum,* as defined in the manuals.

4. T. GRANDIFLORUM (MICHX.) SALISB.

This species does not seem to be so widespread in the state as is the case of previous species. It is most abundant in the northern counties and especially in the boggy soils of the lake region, where it forms fields of many acres, affording a beautiful sight to behold. It is mentioned in published lists from but six counties (9, 14, 23). Specimens in herbaria add seventeen counties to this list. Farwell (16) has named a rose-petalled form, but this seems unjustified on the basis of Indiana specimens because the rose color is the product of age in many of the white-petalled individuals. It is true that some individuals seem to be rose-colored from the beginning. Gates (18) has described *T. grandiflorum* var. trans. *parum* from stations bordering Indiana, viz., Cook county, Illinois; Alma, Michigan, and Mountville, Ohio; but the form does not seem to have been recognized for any Indiana stations, even though the specimens recorded or in herbaria have been taken mainly from territory bordered by these extrastate stations.

5. T. CERNUUM L.

This species is not common in the state. Published reports (9, 14) list it from ten counties and one additional county is represented by herbarium specimens.

5a. T. CERNUUM VAR. MACRATHUM EAMES AND WIEGAND.

This variety, described by Eames and Wiegand (13) from New York, has been reported by Deam (11) from Laporte county. It differs from the species in that its petals are broader and of the oblong-oval or obovate type, while those of the species are of the ovate or lanceolate type; and its anthers are longer than those of the species.

6. T. DECLINATUM (GRAY) GLEASON.

Published records (14, 17, 23) list but three counties for this species. Specimens examined from herbaria add twenty-nine counties to this list.

Examination of several hundred specimens from all parts of the state make it clear that relative length of stigmas and stamens is a character so variable as to be of no value in differentiating *T. declinatum* from *T. erectum* var. *album*. Stigmas vary all the way from 0.5 to 1.5 the length of the stamens. This variation occurs within specimens taken from the same small area, so that there can be no doubt that specimens all belong to the same species. Relative length of filament and anther has also been used to differentiate the two species, but very careful micrometer measurements of several hundred specimens of *T. declinatum* and *T. erectum* indicate that there is no reliable distinction between the two in this regard.

The only character which will serve to distinguish all specimens of *T. declinatum* is the absence of the "wet-dog" odor which is emitted by fresh specimens of *T. erectum.*

6a. T. DECLINATUM FORMA WALPOLEI (FARWELL) N. COMB.

Farwell (16) has described a form of *T. declinatum* with petals, and often with filaments and anthers, red-brown. He considered this to be *T. cernuum* var. *declinatum* forma *Walpolei.* The writer (17) described this form from Washington county, Indiana, in 1924, without naming it except to consider it a variation of *T. declinatum* and without knowledge that Farwell had previously named it. Specimens have since been found in large numbers on the Jose-Dale Estates, Marion county, Indiana. In these specimens all gradations of color can be found, from the deep red-brown to pure white, and pistil length varies all the way from much shorter to much longer than the stamens. Filaments are in all cases very short, averaging about 25 per cent. of the length of the anthers. Specimens are also to be found in the Deam Herbarium from Huntington, Wells and Harrison counties; and in the Butler University Herbarium from Johnson, Bartholomew, Jennings and Steuben counties.

7. T. NIVALE RIDDELL.

This species has been reported (4, 9, 10, 14) in published records from five counties, and specimens in herbaria add seven counties to this list. The species must be considered infrequent in Indiana.

SPECIES DELIMITATION—T. ERECTUM AND T. DECLINATUM

In 1906 Gleason (19) differentiated *T. declinatum* as a separate species from *T. erectum.* The characters used by Gleason and later authors for this differentiation are shown in Table I. Careful study of *T. declinatum* and *T. declinatum Walpolei* as they occur in Indiana shows clearly that of all the characters listed by the authors for both *T. declinatum* and *T. erectum* there is but a single one, viz., the odor, which is not exhibited by *T. declinatum* and its form *Walpolei.*

TABLE I. CHARACTERS USED FOR DIFFERENTIATING T. ERECTUM AND T. DECLINATUM

Author	*T. erectum*	*T. declinatum*
Gray's Manual (27)	Stigma shorter than stamens	Stigma longer than stamens
Britton and Brown (6)	Filament ⅔ the length of anthers	Filament not over ½ length of anthers
	Ovary purple	Ovary white
Gleason (19)	Ovary purple or black	Ovary white or with a tinge of pink
	Petals white to dark purple	Petals white or rarely pink
	Peduncle erect, declined, or rarely nodding	Peduncle nodding or horizontal
	Filaments 50 to 80 per cent. as long as anthers	Filaments 30 to 50 per cent. as long as anthers
Gleason (20)	Stigma shorter than stamens	Stigma equalling or longer than stamens
Small (28)	Stigmas equalling or shorter than stamens	Stigmas equalling or longer than stamens
	Ovary purple	Ovary white
	Ill-scented	Not ill-scented

Color of ovary, used by Gleason (19) and Small (28), is of no value as a differentiating character. The ovary of *T. erectum* is always deep red-brown, but white-petalled forms of *T. declinatum* in Indiana often show deep red-brown ovaries, and the ovary of *T. declinatum Walpolei* is as often red-brown as it is white or pinkish.

Color of petals does not become a differentiating character, since in both species white and colored petals are permitted by the descriptions used by various authors. In a similar manner the character of the peduncle is admitted to be so variable as to be of no value for differentiating purposes.

Ratio of filament length to anther length is used by Gleason (19) and Britton and Brown (6). This character is of no value for diagnostic purposes. Table II shows that the ratio between filament and anther length increases in the following order: *T. declinatum Walpolei* (lowest), intermediates between *T. declinatum Walpolei* and *T. declinatum, T. declinatum* and *T. erectum.* The range of these ratios so overlap, with the minimum for each successive group well below the maximum for the preceding group, that the ratio of any individual specimen cannot be relied upon as a diagnostic character. Specimens of either species are occasionally found with filaments fully 100 per cent. of the length of the anthers.

Relative length of stigma and stamen is used by Robinson and Fernald (27), Gleason (20) and Small (28) for differentiating the two species. This character is of no value for diagnostic purposes, because specimens of both *T. declinatum* and *T. erectum* and their varieties or forms show stigmas varying all the way from much shorter to much longer than the stamens.

The offensive odor suggestive of a "wet dog," which is present in *T. erectum* and absent in *T. declinatum,* is the only character which will separate these forms. But such a character, detectable only in fresh specimens, and being purely a physiological character, is certainly a poor one upon which to base a species difference. The conclusion is forced upon the student of Indiana Trilliums that *T. erectum* and its varieties and forms and *T. declinatum* and its varieties and forms are not sufficiently different to be considered different species. They should be looked upon as one species with a number of biotype differences, appearing throughout the northeastern and eastern range with an ill-scented odor, and usually red-brown flowers, and in the north central states usually without the odor and with petals more often white, but in some localities also red-brown.

I would, therefore, recombine *T. erectum* and *T. declinatum* as one species and conclude that Gleason's separation of them into two species is unwarranted in so far as Indiana specimens are concerned.

TABLE II. FILAMENT AND ANTHER MEASUREMENTS OF T. DECLINATUM AND T. ERECTUM

	FILAMENT				ANTHER				RATIO		
	Min.	Av.	Max.	Range	Min.	Av.	Max.	Range	Min.	Av.	Max.
Walpolei	0.70	1.73	2.16	1.46	8.30	9.95	11.33	3.03	0.08	0.17	0.66* 0.22
Intermediate	2.11	2.39	2.68	0.57	10.76	11.48	12.60	1.84	0.19	0.209	0.25
Declinatum	1.20	3.06	4.60	3.40	7.66	11.48	13.98	6.32	0.12	0.259	0.72* 0.33
Erectum	3.01	4.16	4.98	1.97	6.50	8.77	10.71	4.21	0.35	0.485	0.75* 0.59

*These figures represent an occasional extreme.

DISTRIBUTION OF SPECIES BY COUNTIES

1. T. SESSILE.

Previously reported: Posey, Gibson, Knox, Daviess, Vigo, Tippecanoe, Steuben, Noble, Jay, Delaware, Randolph, Wayne, Fayette, Decatur, Franklin, Dearborn, Jefferson, Clark (9), Putnam (9) (14), White (21), Jasper (29, 30), Monroe (4). Additional reports: Vermillion, Newton, Clay, Parke, Montgomery, Brown, Morgan, Johnson, Boone, Clinton, Carroll, Cass, St. Joseph, Elkhart, Marshall, Howard, Hamilton, Wabash, Harrison, Washington, Grant, Madison, Scott, Jennings, Ripley, Switzerland, Ohio, Henry, Blackford, Wells, Adams, Allen, Dekalb.

2. T. RECURVATUM.

Previously reported: Posey, Gibson, Knox, Daviess, Vigo, Tippecanoe, Cass, Hamilton, Marion, Steuben, Noble, Jay, Delaware, Wayne, Randolph, Fayette, Decatur, Franklin, Jefferson, Clark (9), Monroe (4, 9), Putnam (9, 14), White (29), Jasper (29, 30), Porter (23), Eagle Lake (7). Additional reports: Lake, Newton, Warren, Vermillion, Fountain, Parke, Clay, Sullivan, Vanderburg, Warrick, Laporte, Carroll, Clinton, Montgomery, Boone, Owen, Greene, Martin, Dubois, Perry, Crawford, Orange, Lawrence, Morgan, St. Joseph, Marshall, Miami, Howard, Tipton, Johnson, Bartholomew, Harrison, Floyd, Scott, Elkhart, Kosciusko, Wabash, Huntington, Grant, Madison, Hancock, Henry, Rush, Jennings, Blackford, Wells.

2a. T. RECURVATUM FORMA LUTEUM.

Monroe.

3. T. ERECTUM.

Posey, Gibson, Knox, Daviess, Vigo, Putnam, Tippecanoe, Hamilton, Steuben, Noble, Jay, Delaware, Randolph, Wayne, Fayette, Decatur, Franklin, Dearborn, Jefferson, Clark (9), Monroe (8), Marion (12), Marshall (15). New reports: Harrison, Hancock, Dekalb, Allen, St. Joseph.

3a. T. ERECTUM ALBUM.

Dekalb, Allen, Hancock, Jefferson, Clark, Floyd, Harrison, Gibson.

4. T. GRANDIFLORUM.

Previously reported: Posey, Gibson, Noble, Steuben (9), Putnam (14), Porter (23). New reports: Greene, Harrison, Parke, Fountain, Laporte, St. Joseph, Elkhart, Lagrange, Kosciusko, Whitley, Allen, Wabash, Wells, Randolph, Union, Dekalb, Marshall.

5. T. CERNUUM.

Previously reported: Vigo, Marion, Delaware, Jefferson, Franklin, Wayne, Randolph, Jay, Steuben (9), Putnam (9, 14). New report: Scott.

5a. T. CERNUUM MACRANTHUM.

Previously reported: Laporte (11).

6. T. DECLINATUM.

Previously reported: Putnam (14), Porter (23), Washington (17). New reports: Newton, Posey, Carroll, Tippecanoe, Clinton, Boone, Montgomery, Parke, Clay, Owen, Morgan, Monroe, Lawrence, Crawford, Perry, Harrison, Floyd, Jackson, Brown, Bartholomew, Jennings, Johnson, Decatur, Ripley, Dearborn, Ohio, Jefferson, Marion, Hancock, Pulaski, Marshall, Grant, Huntington, Wells.

6a. T. DECLINATUM WALPOLEI.

Huntington, Harrison, Wells (Deam's Herbarium), Marion, Johnson, Bartholomew, Jennings, Washington, Butler University Herbarium.

7. T. NIVALE.

Previously reported: Tippecanoe (9, 10), Putnam (9, 14), Monroe (4, 9), Decatur (9), Clark (9). New reports: Warren, Parke, Montgomery, Owen, Marion, Lawrence, Harrison.

New counties listed for above species are based upon herbarium specimens in one or more of the following herbaria, to whose directors I take this opportunity of expressing my appreciation for their kindness in permitting me to study their material on the genus: Indiana University, Wabash College, DePauw University, Deam's Herbarium, and University of Notre Dame.

SUMMARY

1. *Trillium sessile* forma *luteum* and *T. declinatum Walpolei* are listed for the first time from Indiana.

2. *T. recurvatum* forma *luteum* is described as a new form.

3. Indiana specimens of *T. erectum* and *T. declinatum* are identical in every morphological character and are considered to be one species.

4. *T. declinatum, T. declinatum Walpolei* and *T. erectum album* are considered to be biotype variations of *T. erectum* and not worthy of species differentiation.

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LIFE-FORMS AND BIOLOGICAL SPECTRA OF THE FLORA OF BACON'S SWAMP, INDIANA

By Alice Phillips

During the nineteenth and the first part of the twentieth century no detailed statistical studies of vegetation in relation to climate had been devised. The work relating to the two was broad, general and superficial. Climatic formations of the world had been described and classified by plant geographers and early ecologists, as Schimper, Warming, Cowles and others. Work was done classifying regions as xerophytic, mesophytic or hydrophytic, but no methods had been published giving means of ascertaining in more detail the degree of xerophytism, mesophytism or hydrophytism. In 1909, C. Raunkiaer, of Copenhagen, Denmark, published a paper on "Life-Forms and Statistical Methods." This work concerned methods which the author had devised to measure the total climatic influences on plants by means of the plants themselves. It was an effort to apply quantitative methods to plants and to classify them as to life-form. The factor selected by Raunkiaer was the adaptation of plants to the critical season as indicated by the degree and nature of the protection afforded dormant perennating buds. Raunkiaer, in addition to his theory, classified four hundred plants carefully selected from the entire world, fitting each into its proper life-form (as based on the protection of the perennating bud), and called the percentages of the groups of growth forms a world normal biological spectrum. Raunkiaer stated that a count of the different kinds of plants according to his classification would indicate the nature of the habitat and give a biological spectrum for it.

The "life-form" method of Raunkiaer came into immediate use. In 1913, W. G. Smith (6) published in the *Journal of Ecology* an article translating in part and discussing Raunkiaer's life-forms and statistical methods. In 1915, Ove Paulsen (5), a Danish scientist, gave an account of his use of Raunkiaer's method in comparing the vegetation of different localities in the North American desert regions with that of the Asiatic steppes by means of biological spectra of each vegetation. He noted that, coincident with an increase of xerophytism, there was a definite trend in the change of the life-form percentages. In 1918, Fuller and Bakke (4) attempted to coincide biological spectra with the physiognomy of vegetation. They state:

"Formation spectra have both biological and physiognomical significance; biologically they characterize the formations with the life-form which primarily dominates; they also characterize the formations with respect to the life-forms which determine the aspect of the physiognomy of the vegetation."

R. S. Adamson (1), in 1918, dealt with some extensive work which he had done in South Africa on Table Mountain. He used Raunkiaer's method in indicating the relationship of plant communities, especially in regard to succession. He employed spectra of the life-forms to show similarities and differences in the various stages of succession from the xerophytic to the climax stages.

THE VEGETATION OF BACON'S SWAMP

The present investigation into life-forms is in connection with the various vegetational associations at Bacon's Swamp, Marion county, Indiana. Bacon's Swamp is an extinct glacial lake, near the southern boundary of the late Wisconsin glaciation. It has been filled with peat deposited partly under bog and partly under swamp conditions.

S. A. Cain (2) has dealt with the vegetational changes to which the swamp has gradually been subjected. He has divided these changes into two types of succession, a bog succession and a swamp succession (Figure 1). Of the former, there is but one stage remaining, a wet meadow occupying the center of the swamp. The substratum of the meadow is organic, being made up largely of the remains of Sphagnum and other bog plants. The peat is acid in its reaction. The meadow is now dominated by *Calamagrostis canadensis.*[1] Associated with it are such species as *Dulichium arundinaceum, Hypericum virginicum* and *Aspidium thelypteris.* Among the plants which indicate the previous bog conditions are such relics as *Sphagnum* (in small amounts), *Decodon verticillatus, Rosa palustris* and *Potentilla palustris.*

Of the swamp succession, there remain several stages. *Carex impressa* is found immediately surrounding the wet meadow, growing in somewhat deeper water. In turn, it gives way to a growth of *Typha latifolia.* Typha is succeeded by a zone of buttonbush, occupying the region of deepest water, usually called the moat. The buttonbush zone is very well defined, although there are indications that lead to the

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[1] Nomenclature: Gray's New Manual of Botany, 7th Ed.

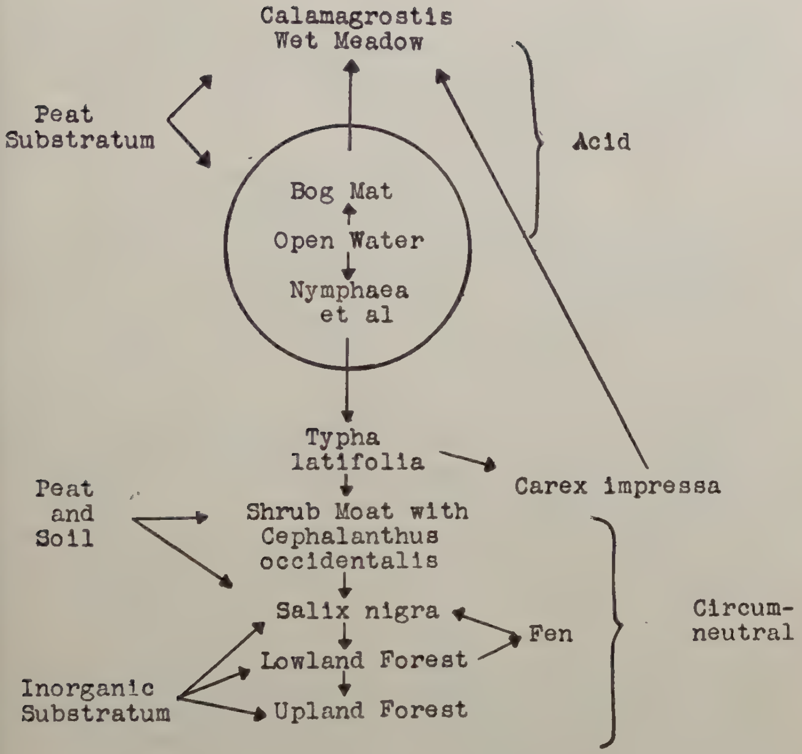


Figure 1

conclusion that the growth of Cephalanthus was at one time wider spread than at present. The next stage represented is just beyond the Cephalanthus and is dominated by *Salix nigra*. A lowland forest, containing principally *Acer rubrum, Populus deltoides, Fraxinus profunda* and *Nyssa sylvatica,* succeeds the black willow zone. This in turn prepares the way for an upland or beech-maple climax forest. There are places in the swamp where a fen growth prevails between the black willow zone and the lowland forest. This growth is probably a part of a secondary succession taking place at points where the vegetation of the primary succession was destroyed. The substratum underlying the stages of the swamp succession is circumneutral in reaction, in contrast to the acid reaction of the bog substratum.

There are a few hydrophytic associations with *Nymphaea,* etc., scattered over the swamp. The succession is not one of the bog type, due to the present half-drained character of the swamp. There are also certain floating hydrophytes, as *Lemna minor, Lemna trisulca* and *Wolffia columbiana,* found scattered about the swamp, intermingled with the rooted hydrophytic or the marsh plants.

LIFE-FORM CLASSES

It is very interesting to note how the plants of these various successions and their stages are classified according to Raunkiaer's method.

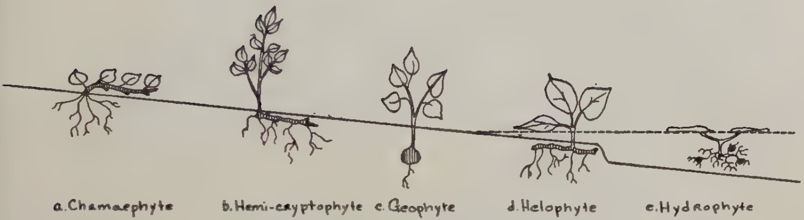
Raunkiaer proposed five general life-form groups, three of which are subdivided into smaller groups. The five groups and their subdivisions are:

The PHANEROPHYTES, which are plants having their dormant buds on branches which project into the air and thus are woody plants. These may further be classified according to size, since this is determined by the relation between the plants and the humidity of the environment. The subgroups are: (1) the *megaphanerophytes,* which have a stature of over 30 metres; (2) the *mesophanerophytes,* 8-30 metres tall; (3) the *microphanerophytes,* ranging in height from 2-8 metres; and (4) the *nanophanerophytes,* which are under 2 metres in height.

The CHAMAEPHYTES include plants with their buds perennating on the surface of the ground or just above it (not exceeding 25 cm above it), so that in temperate and arctic regions they will be protected in winter by the snow, while in other localities with a dry season some protection will be afforded by plant remains. The buds are thus better protected than in the phanerophytes.

The HEMICRYPTOPHYTES are plants with their dormant buds in the upper crust of the soil, just below the surface; the aerial parts are herbaceous and die away in the critical period, so that they form an additional protection to the earth-buds. In the present work, those plants whose buds were buried not more than one inch in the soil were considered hemicryptophytes.

The CRYPTOPHYTES are the plants with their dormant parts entirely and well hidden. There are three divisions of the Cryptophytes,—the *Geophytes,* the *Helophytes* and the *Hydrophytes.* In the case of the geophytes, there are bulbs, rhizomes, tubers or similar structures deep below the soil surface. The helophytes are characterized by semiaquatic dormant buds and are marsh plants. The helophytes do not include all marsh species, but only such plants as are cryptophytes and have



a. Chamaephyte b. Hemi-cryptophyte c. Geophyte d. Helophyte e. Hydrophyte

Fig. 1. Life Forms of Raunkiaer

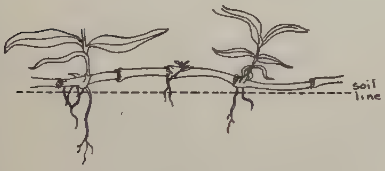


Fig. 2. Phlox divaricata, Chamaephyte

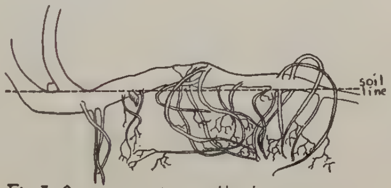


Fig. 3. Asarum canadense, Hemi-cryptophyte

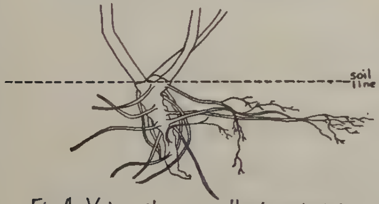


Fig. 4. Viola papilionaceae, Hemi-cryptophyte

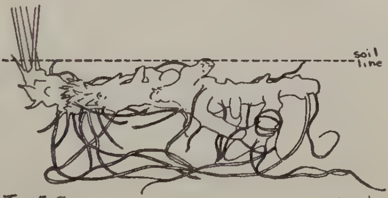


Fig. 5. Geranium maculatum, Hemi-cryptophyte

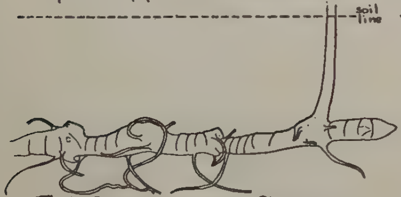


Fig. 6 Smilacina racemosa, Geophyte

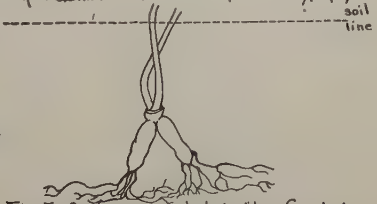


Fig 7. Anémonella thalictroïdes, Geophyte

their buds buried at the bottom of the water or in the subjacent soil. The hydrophytes are the water plants and have either perennating rhizomes or similar structures or winter buds beneath the water.

The Therophytes are plants of the favorable season and live through the critical season as seeds; hence they are annual plants.

A classification of the flora of Bacon's Swamp according to the above groups gave the biological spectrum below (Table I). Included with the spectrum for the total flora are classifications for the various associations.

TABLE I. BIOLOGICAL SPECTRA OF BACON'S SWAMP, INDIANA

The abbreviations used for the different life forms are:

T—therophytes
Ch—chamaephytes
H—hemicryptophytes
G—geophytes
Mg—megaphanerophytes
Ms—mesophanerophytes
M—microphanerophytes
N—nanophanerophytes
Hl—helophytes
Hy—hydrophytes

Spectrum	Total Flora	T	Ch	H	G	Mg	Ms	M	N	Hl	Hy
Normal	400	13	9	27	3	3	6	17	20	1	
Total flora	164	2.43	1.83	22.53	21.32	9.13	17.66	12.18	4.26	4.87	3.65
Upland flora	108	1.85	1.85	21.27	26.82	11.10	21.27	12.02	3.70	....	....
Lowland forest	18	5.55	......	27.75	....	16.65	38.85	....	5.55	5.55	....
Fen	17	5.88	......	35.28	29.95	....	....	....	5.88	23.52	....
Moat	10	......	......	....	....	....	....	80.00	20.00	....	....
Aquatic	8	......	......	....	....	....	....	....	....	25.00	75.00
Wet meadow	17	5.88	5.88	29.95	5.88	....	....	17.64	11.76	23.52	....

Below is given the flora of Bacon's Swamp, classified according to Raunkiaer's method.

I. PHANEROPHYTES

(1) Megaphanerophytes

		Association
1.	*Acer rubrum*	Lowland
2.	*A. saccharum*	Upland
3.	*Carya ovata*	Upland
4.	*Fagus grandifolia*	Upland

		Association
5.	*Fraxinus americana*	Upland
6.	*Juglans nigra*	Upland
7.	*Liriodendron tulipifera*	Lowland
8.	*Platanus occidentalis*	Upland
9.	*Quercus alba*	Upland
10.	*Q. macrocarpa*	Upland
11.	*Q. muhlenbergii*	Upland
12.	*Q. palustris*	Lowland
13.	*Q. rubra*	Upland
14.	*Q. velutina*	Upland
15.	*Ulmus americana*	Upland

(2) Mesophanerophytes

1.	*Acer nigrum*	Upland
2.	*Aesculus glabra*	Upland
3.	*Carpinus caroliniana*	Upland
4.	*Carya cordiformis*	Upland
5.	*Celtis occidentalis*	Upland
6.	*Cercis canadensis*	Upland
7.	*Cornus florida*	Upland
8.	*Fraxinus lanceolata*	Upland
9.	*F. nigra*	Upland and lowland
10.	*F. pennsylvanica*	Upland
11.	*F. profunda*	Lowland
12.	*F. quadrangulata*	Upland
13.	*Gleditsia triacanthos*	Upland
14.	*Gymnocladus dioica*	Upland
15.	*Maclura pomifera*	Upland
16.	*Morus rubra*	Upland
17.	*Nyssa sylvatica*	Lowland
18.	*Ostrya virginiana*	Upland
19.	*Populus deltoides*	Lowland
20.	*P. grandidentata*	Upland
21.	*Prunus serotina*	Upland
22.	*Psedera quinquefolia*	Upland
23.	*Quercus bicolor*	Lowland
24.	*Rhus toxicodendron*	Upland
25.	*Salix nigra*	Lowland
26.	*Tecoma radicans*	Upland

		Association
27.	*Ulmus fulva*	Lowland
28.	*Viburnum lentago*	Upland
29.	*Vitis bicolor*	Upland

(3) MICROPHANEROPHYTES

1.	*Aronia floribunda*	Moat
2.	*Asimina triloba*	Upland
3.	*Benzoin aestivale*	Upland
4.	*Cephalanthus occidentalis*	Moat and wet meadow
5.	*Cornus amomum*	Upland and moat
6.	*Crataegus sp?*	Upland
7.	*Evonymus atropurpureus*	Upland
8.	*Ilex verticillata*	Moat
9.	*Menispermum canadense*	Upland
10.	*Prunus nigra*	Upland
11.	*P. virginiana*	Upland
12.	*Ptelea trifoliata*	Upland
13.	*Rhus glabra*	Upland
14.	*Salix discolor*	Moat and wet meadow
15.	*S. discolor var. eriocephala*	Moat and wet meadow
16.	*S. sericea*	Moat
17.	*Sambucus canadensis*	Upland
18.	*Smilax hispida*	Upland
19.	*S. rotundifolia*	Upland
20.	*Xanthoxylum americanum*	Moat

(4) NANOPHANEROPHYTES

1.	*Ribes cynosbati*	Upland
2.	*Rosa palustris*	Moat and wet meadow
3.	*Rubus allegheniensis*	Upland
4.	*R. hispidus*	Fen
5.	*R. occidentalis*	Upland
6.	*Solanum dulcamara*	Upland and lowland
7.	*Spiraea salicifolia*	Moat and wet meadow

II. CHAMAEPHYTES

1.	*Decodon verticillatus*	Wet meadow
2.	*Evonymus obovatus*	Upland
3.	*Phlox divaricata*	Upland

III. HEMICRYPTOPHYTES

		Association
1.	*Agastache nepetoides*	Upland
2.	*Asarum canadense*	Upland
3.	*Asclepias incarnata*	Fen
4.	*Aster laevis*	Upland
5.	*Bidens trichosperma*	Fen
6.	*Calamagrostis canadensis*	Wet meadow
7.	*Carex crinita*	Lowland
8.	*C. laxiflora*	Upland
9.	*C. sp?*	Lowland
10.	*Cystopteris fragilis*	Upland
11.	*Geranium maculatum*	Upland
12.	*Geum vernum*	Upland
13.	*Heuchera americana*	Upland
14.	*Hybanthus concolor*	Upland
15.	*Hydrophyllum virginianum*	Upland
16.	*Hypericum virginicum*	Wet meadow
17.	*Isopyrum biternatum*	Upland
18.	*Lobelia cardinalis*	Fen
19.	*L. siphilitica*	Fen
20.	*Luzula campestris var. multiflora*	Upland
21.	*Nepeta cataria*	Upland
22.	*Onoclea sensibilis*	Lowland and upland
23.	*Osmorhiza longistylis*	Upland
24.	*Penthorum sedoides*	Fen
25.	*Polemonium reptans*	Upland
26.	*Polygonum hydropiperoides*	Wet meadow
27.	*P. muhlenbergii*	Wet meadow
28.	*Ranunculus abortivus*	Lowland
29.	*R. recurvatus*	Lowland
30.	*Scirpus cyperinus*	Wet meadow and fen
31.	*Stellaria pubera*	Upland
32.	*Stylophorum diphyllum*	Upland
33.	*Viola papilionaceae*	Upland
34.	*V. rafinesquii*	Upland
35.	*V. scabriuscula*	Upland
36.	*V. striata*	Upland
37.	*Woodsia obtusa*	Upland

IV. CRYPTOPHYTES

(1) Geophytes

		Association
1.	*Actea alba*	Upland
2.	*Allium sp?*	Upland
3.	*Anemonella thalictroides*	Upland
4.	*Apios tuberosa*	Fen
5.	*Arisaema dracontium*	Upland
6.	*A. triphyllum*	Upland
7.	*Botrychium virginianum*	Upland
8.	*Camassia esculenta*	Upland
9.	*Claytonia virginica*	Upland
10.	*Dentaria laciniata*	Upland
11.	*Desmodium canadense*	Fen
12.	*Dicentra canadensis*	Upland
13.	*D. cucullaria*	Upland
14.	*Epifagus virginiana*	Upland
15.	*Equisetum hyemale*	Upland
16.	*Eriginea bulbosa*	Upland
17.	*Erythronium americanum*	Upland
18.	*E. albidum*	Upland
19.	*Eupatorium perfoliatum*	Fen
20.	*Hydrastis canadensis*	Upland
21.	*Hydrophyllum appendiculatum*	Upland
22.	*H. macrophyllum*	Upland
23.	*Iris versicolor*	Fen
24.	*Juncus canadensis*	Wet meadow
25.	*Lycopus uniflorus*	Fen
26.	*Phryma leptostachya*	Upland
27.	*Phytolacca decandra*	Upland
28.	*Podophyllum peltatum*	Upland
29.	*Polygonatum biflorum*	Upland
30.	*P. commutatum*	Upland
31.	*Sanguinaria canadensis*	Upland
32.	*Smilacina racemosa*	Upland
33.	*Tradescantia virginiana*	Upland
34.	*Trillium recurvatum*	Upland
35.	*T. sessile*	Upland

(2) HELOPHYTES

		Association
1.	*Aspidium thelypteris*	Wet meadow
2.	*Carex impressa*	Wet meadow
3.	*Dulichium arundinaceum*	Wet meadow and fen
4.	*Potentilla palustris*	Wet meadow
5.	*Saggitaria latifolia*	Aquatic and fen
6.	*Saururus cernuus*	Lowland and fen
7.	*Sium cicutaefolium*	Fen
8.	*Typha latifolia*	Aquatic

(3) HYDROPHYTES

1.	*Lemna minor*	Aquatic
2.	*L. trisulca*	Aquatic
3.	*Nymphaea advena*	Aquatic
4.	*Salvinia natans*	Aquatic
5.	*Ranunculus delphinifolius*	Aquatic
6.	*Wolffia columbiana*	Aquatic

V. THEROPHYTES

1.	*Galium aparine*	Upland
2.	*Gratiola virginiana*	Upland
3.	*Impatiens biflora*	Lowland
4.	*Polygonum saggitatum*	Wet meadow and fen

DISCUSSION

While making the above classification, difficulties were encountered in several instances. The geophytes and helophytes presented certain problems. During the rainy season of the year, some plants appear to be helophytes, yet in the dry season they have the life-form of a geophyte or hemicryptophyte. It was with some difficulty that these amphibious plants, as *Saururus cernuus,* were classified. They were placed in the groups to which they belonged for the greater part of the year.

There were certain geophytes and hemicryptophytes which were doubtful cases also. There are present other confusing factors besides a certain overlapping of the soil depths at which the perennating buds are hidden. Differences in the amount of leaf litter, unprotected soils versus protected soils and the angle of slope must be taken into consideration. A number of studies were made of the doubtful plants and they were classified according to the growth form which the majority of the cases assumed.

In the interpretation of the biological spectra, Table I, the difference in the general types of life-forms found in each association is very clear. The wet meadow of the bog succession contains some shrubs, marsh plants and hemicryptophytes which are able to stand excessive moisture, and an occasional therophyte which comes in the less moist places in the dry seasons. The wet meadow contains more variety of life-forms than does any other association with the exception of the upland climax forests. The moat is vegetated entirely by densely grown shrubs and small trees. In contrast, the plant life of the fen is made up of a large group of hemicryptophytes, many species of marsh plants, a number of geophytes and a few annuals coming in in the dry season. The lowland or swamp forest contains many species of trees and shrubs, with a few marsh plants and a rather large number of hemicryptophytes. There are some annuals which come into the lowland forest in the dry season. The upland forest has represented in it all the forms with the exception of the marsh and aquatic plants. The phanerophytes are dominant here with a few annuals and a very large percentage of geophytes.

It will be noticed that there is a gradual decline in the number of species and in the number of life-forms from the climax or upland forest to the original hydrophytic stage. There is a rise in the number of species and life-forms from the hydrophytic association to the wet meadow stage.

The phanerophytes are predominant with 43.23 per cent. of the total flora assuming this life-form. The cryptophytes are next with a percentage of 29.84, closely followed by the hemicryptophytes with a percentage of 22.53. The therophytes and chamaephytes occur in fewer cases than any of the other life-forms. The low percentage of therophytes is probably due to the fact that all weeds and roadside plants were omitted, only native species being included in the flora.

SUMMARY

1. There is a gradual increase in the number of species and of life-forms from the hydrophytic association through each succeeding stage of the swamp succession. The beech-maple forest or climax stage con-

tains a greater number of species and life-forms than any of the other associations.

2. There is an increase in the number of species and life-forms from the aquatic stage to the wet meadow, which is the only remaining stage of the bog succession.

3. The classification of plants of various associations into life-forms gives a definite result, showing the difference in the edaphic and atmospheric effects of the surroundings of each association on the method of protection which the flora of that association assumes for the perennating buds. In the upland forest, a predominance of phanerophytes with slightly protected buds are found, while in the aquatic situations the buds are well protected, the plants all being cryptophytes.

NOTE: This work was done in connection with *magna cum laude* requirements for an A. B. degree at Butler University. The subject was suggested by Professor Stanley A. Cain, who has rendered many other helpful suggestions as the work progressed.

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KEY TO GENERA OF FERNS AND FERN ALLIES

By RAY C. FRIESNER

The keys to be found in the Manuals used for taxonomic study often require the student using them to have a greater knowledge of the species under study than is obtainable from the specimen at hand. For example, the indusium regularly drops from the sorus in some genera when the fronds are young, while in other genera, indusia are never present. Examples of these are found, in the case of the former condition, in Cystopteris and Woodsia, and in the case of the latter condition, in Polypodium and Phegopteris. How is the student just beginning taxonomic work on the ferns to know, when he encounters a fruiting frond with no indusia, whether it is a case of entire absence of indusia or a species from which the indusia drop off early? He should, of course, examine a number of specimens, but the working collection available for his study does not always have both young and old specimens of each species. It should have, to be sure, but it is not always expedient for the instructor to have material representing all ages of fronds. Further, suppose the student is identifying material of his own collection instead of a set prepared for him by some one else, and he wishes to know today whether the absence of an indusium is a fixed character. He cannot always wait a year to determine his point by observation on younger fronds.

Keys, to be pedagogically sound, should meet such situations by permitting the student to take either line of diagnosis at such a point and still bring him out to the proper genus or species. The characters used in differentiating groups, whether families, genera or species, should always be definitely contrasted. One member of a set should not deal with one characteristic and the other with a different characteristic, but both should deal with the same feature of the plants. All members of a set of characters should be kept together, thus making the key more readily followed when used for identification purposes. Every second set of characters should be indented slightly, thus sharply setting off the different sets from each other. Characters which are discernible at different seasons of the year should not be brought together in the same key; *e. g.*, flower characters of trees are present for so short a period that they should not be used in a key based primarily upon vegetative characters. Members of a set of characters should be as brief as possible, no attempt being made to describe in detail. Relative terms, such as large and small or wide and narrow, should not be used unless definite measurements accompany them.

No attempt has been made to carry this key to species. Species differentiation is referred to the Manuals, such as Gray or Britton and Brown (for Northeastern United States). The figures in the key following generic names refer to pages in Gray's Manual, 7th edition (G), or Britton and Brown, 2nd edition (BB), where the genus is described and keys are given for the determination of species.

KEY

1. Plants floating on surface of boggy waters.......... 2
1. Plants not floating.......... 3
    2. Leaves apparently 2-ranked, densely papillose on dorsal side .... *Salvinia,* G 50; BB 36
    2. Leaves closely imbricated, glabrous on dorsal surface.......... *Azolla,* G 50; BB 38
3. Plants twining or climbing.......... *Lygodium,* G 46; BB 9
3. Plants neither twining nor climbing 4
    4. Plants very slender, filiform, tortuous, 3-8 cm long.......... *Schizaea,* G 45; BB 9
    4. Leaves 4-foliolate, plants rooted in mud of shallow water .... *Marsilea,* G 49; BB 36
    4. Leaves reduced to mere vestigial scales whorled at nodes of jointed stems .... *Equisetum,* G 51; BB 39
    4. Leaves very long and narrow, 3-20 by 0.5-1.0 cm, very closely imbricated on short corm-like stem.......... *Isoetes,* G 58; BB 50
    4. Leaves small, 2-10 mm long, very closely imbricated.......... 5
    4. Leaves larger, broader, frond-like, common true ferns.......... 6
5. Homosporous, *i. e.,* spores of one type only.......... *Lycopodium,* G 54; BB 43
5. Heterosporous, *i. e.,* spores of two types in regard to size.......... *Selaginella,* G 57; BB 48

6. Fertile and vegetative fronds entirely separate and conspicuously unlike each other 7
6. Not differentiated into separate vegetative and fertile fronds, or if so they are not conspicuously different from each other 10
7. Stipe of fertile frond clothed with dense brown tomentum. Vegetative fronds may be similar in this regard .... *Osmunda cinnamomea*, G 47; BB 7
7. Stipe of fertile frond not as above 8
8. Fertile frond bipinnate 9
8. Fertile frond once-pinnate .... *Onoclea*, G 45; BB 11
9. Fertile frond 12.5-40 cm long. Fertile portion of more than five pinnate divisions .... *Onoclea*, G 45; BB 10
9. Fertile frond 5-12.5 cm long. Fertile portion of five closely crowded pinnate divisions .... *Schizaea*, G 45; BB 9
10. Individual fronds composed of both entirely vegetative and entirely fertile pinnae 11
10. Sori borne on the backs of the otherwise vegetative fronds 14
11. Vegetative segment of frond simple .. *Ophioglossum*, G 47; BB 1
11. Vegetative segment of frond compound 12
12. Fertile segment of frond distant, above the vegetative .. 13
12. Fertile segments merely the contracted terminal portion of the ordinary frond ...... *Polystichum*, G 40; BB 16
12. Fertile pinnae 1-8, in the middle portion of the vegetative frond .... *Osmunda Claytoniana*, G 47; BB 8
13. Frond with fleshy stipe, ultimate divisions with toothed margins .... *Botrychium*, G 47; BB 3
13. Frond without fleshy stipe, ultimate divisions with entire margins .... *Osmunda regalis*, G 46; BB 7
14. Sori not covered with an indusium; or the indusium may drop off when young 15
14. Sori covered with an indusium. Forms in which indusium drops when young may be sought in either of these two characters 18
15. Fronds once-pinnatifid .... *Polypodium*, G 34; BB 35
15. Fronds twice-pinnatifid to 4-pinnate, green on both surfaces 16
15. Fronds 1-4 pinnate, lower surface hairy, tomentose, or covered with a white or waxy powder .... *Notholaena*, G 35; BB 35

16. Rachis winged between the pinnae .... *Phegopteris,* G 35; BB 23
16. Rachis not winged between pinnae 17
17. Stipes, rachis and ventral side of midvein minutely chaffy .... *Woodsia,* G 43; BB 11
17. Stipes, rachis and ventral side of midvein without chaff .... *Cystopteris,* G 43; BB 14
18. Indusium false, *i. e.,* formed from the revolute margin of the frond 19
18. Indusium true, *i. e.,* not formed from the revolute margin of the frond 24
19. Sori forming a more or less continuous marginal band 20
19. Sori not forming a more or less continuous marginal band 23
20. Stipe and rachis blackish or purplish 21
20. Stipe and rachis chestnut-brown .... *Cheilanthes,* G 36; BB 33
20. Stipe straw-colored or greenish 22
21. Stipe and rachis smooth and shining, without scales .... *Notholaena,* G 35; BB 35
21. Stipe and rachis clothed with brownish scales .... *Cheilanthes,* G 36; BB 33
22. Fronds not dimorphic, stipe and rachis smooth or densely chaffy throughout; pinnules glabrous or slightly pubescent on ventral surface near margins and midvein .... *Pteris,* G 36; BB 31
22. Fronds dimorphic, fertile narrower than sterile, chaff limited to base of stipe, pinnules glabrous .... *Cryptogramma,* G 36; BB 52
23. Sori small, globular, at the apex of free veins, appearing as if raised upon a pedestal .... *Dicksonia,* G 44; BB 14
23. Sori oblong or somewhat crescent-shaped .... *Adiantum,* G 35; BB 31
24. Fronds transparent, consisting of a single layer of cells only .... *Trichomanes,* G 33; BB 8
24. Fronds thicker, of more than one layer of cells 25
25. Sori more or less elongated, straight or curved 26
25. Sori more or less rounded 29
25. Sori rounded when young, but confluent when old .... *Polystichum,* G 40; BB 16

26. Veins reticulated 27

26. Veins free 28

27. Sori forming a chain-like row on either side of midvein .... *Woodwardia*, G 37; BB 34

27. Sori scattered, some parallel with midvein and some parallel with lateral veins .... *Camptosorus*, G 40; BB 25

28. Sori single, frond once-pinnatifid to 4-pinnate .... *Asplenium*, G 38; BB 26

28. Sori confluent in pairs, frond entire or merely undulate .... *Scolopendrium*, G 40; BB 25

29. Indusium attached by the center 30

29. Indusium attached by one side .... *Cystopteris*, G 43; BB 14

29. Indusium inferior, *i. e.*, attached at two or more points beneath the sporangia 31

30. Indusium round, without a sinus .... *Polystichum*, G 40; BB 16

30. Indusium round or reniform, with a sinus .... *Aspidium*, G 41; BB 17

31. Indusium two-valved, cup-shaped .... *Dicksonia*, G 44; BB 14

31. Indusium with more than two valves .... *Woodsia*, G 43; BB 11

CHECK-LIST OF INDIANA FERNS AND FERN ALLIES

The following sixty-five species of ferns and fern allies are to be found growing out of cultivation in Indiana:

Adiantum pedatum L.
Aspidium cristatum Sw.
A. Goldianum Hook.
A. marginale Sw.
A. noveboracense (L) Sw.
A. spinulosum (Mueller) Sw.
A. spinulosum intermedium (Muhl.) Eaton.
A. Thelypteris (L) Sw.
Asplenium acrostichoides Sw.
A. angustifolium Michx.
A. ebenoides R. A. Scott.
A. Filix-femina (L) Bernh.
A. pinnatifidum Nutt.
A. platyneuron (L) Oakes.
A. Ruta-muraria L.
A. Trichomanes L.
Azolla caroliniana Willd.
Botrychium obliquum Muhl.
B. obliquum dissectum (Spreng) Clute.
B. ternatum intermedium D. C. Eaton.
B. simplex E. Hitch. (Doubtful.)
B. obliquum Muhl.
B. virginianum (L) Sw.

Camptosorus rhizophyllus (L) Link.
Cheilanthes lanosa (Michx.) Walt.
Cystopteris bulbifera (L) Bernh.
C. fragilis (L) Bernh.
Dicksonia punctilobula (Michx.) Gray.
Equisetum arvense L.
E. fluviatile L.
E. hyemale L.
E. hyemale intermedium A. A. Eaton.
E. laevigatum A. Br.
E. robustum A. Br.
E. variegatum Schleich.
Lycopodium clavatum L.
L. complanatum L.
L. inundatum L.
L. lucidulum Michx.
L. obscurum L.
L. obscurum dendroideum (D. C. Eaton) Michx.
L. porophilum (L. and U.) Clute.
L. selago L.
Marsilea quadrifolia L.
Onoclea sensibilis L.
O. Struthiopteris (L) Hoffm.
Ophioglossum vulgatum L.
Osmunda cinnamomea L.
O. cinnamomea frondosa Gray.
O. cinnamomea incisa J. W. Huntington.
O. Claytoniana L.
O. regalis L.
Pellaea atropurpurea (L) Link.
Phegopteris Dryopteris (L) Fee.
P. hexagonoptera (Michx.) Fee.
P. polypodiodes (L) Fee.
Polystichum acrostichoides (Michx.) Schott.
P. acrostichoides Schweinitzii (Beck) Small.
Polypodium polypodioides (L) A. S. Hitch.
P. vulgare L.
Pteris aquilina L.
Selaginella apus (L) Spreng.
S. rupestris (L) Spreng.
Woodsia obtusa (Spreng.) Torr.
Woodwardia virginica (L) Sw.

KEY TO GENERA OF FERNS AND FERN ALLIES

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By RAY C. FRIESNER

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KEY TO GENERA OF FERNS AND FERN ALLIES

By Ray C. Friesner

The keys to be found in the Manuals used for taxonomic study often require the student using them to have a greater knowledge of the species under study than is obtainable from the specimen at hand. For example, the indusium regularly drops from the sorus in some genera when the fronds are young, while in other genera, indusia are never present. Examples of these are found, in the case of the former condition, in Cystopteris and Woodsia, and in the case of the latter condition, in Polypodium and Phegopteris. How is the student just beginning taxonomic work on the ferns to know, when he encounters a fruiting frond with no indusia, whether it is a case of entire absence of indusia or a species from which the indusia drop off early? He should, of course, examine a number of specimens, but the working collection available for his study does not always have both young and old specimens of each species. It should have, to be sure, but it is not always expedient for the instructor to have material representing all ages of fronds. Further, suppose the student is identifying material of his own collection instead of a set prepared for him by some one else, and he wishes to know today whether the absence of an indusium is a fixed character. He cannot always wait a year to determine his point by observation on younger fronds.

Keys, to be pedagogically sound, should meet such situations by permitting the student to take either line of diagnosis at such a point and still bring him out to the proper genus or species. The characters used in differentiating groups, whether families, genera or species, should always be definitely contrasted. One member of a set should not deal with one characteristic and the other with a different characteristic, but both should deal with the same feature of the plants. All members of a set of characters should be kept together, thus making the key more readily followed when used for identification purposes.

Every second set of characters should be indented slightly, thus sharply setting off the different sets from each other. Characters which are discernible at different seasons of the year should not be brought together in the same key; *e. g.*, flower characters of trees are present for so short a period that they should not be used in a key based primarily upon vegetative characters. Members of a set of characters should be as brief as possible, no attempt being made to describe in detail. Relative terms, such as large and small or wide and narrow, should not be used unless definite measurements accompany them.

No attempt has been made to carry this key to species. Species differentiation is referred to the Manuals, such as Gray or Britton and Brown (for Northeastern United States). The figures in the key following generic names refer to pages in Gray's Manual, 7th edition (G), or Britton and Brown, 2nd edition (BB), where the genus is described and keys are given for the determination of species.

KEY

1. Plants floating on surface of boggy waters.................... 2
1. Plants not floating.................... 3
    2. Leaves apparently 2-ranked, densely papillose on dorsal side ....*Salvinia,* G 50; BB 36
    2. Leaves closely imbricated, glabrous on dorsal surface.................... *Azolla,* G 50; BB 38
3. Plants twining or climbing....................*Lygodium,* G 46; BB 9
3. Plants neither twining nor climbing 4
    4. Plants very slender, filiform, tortuous, 3-8 cm long.................... *Schizaea,* G 45; BB 9
    4. Leaves 4-foliolate, plants rooted in mud of shallow water ....*Marsilea,* G 49; BB 36
    4. Leaves reduced to mere vestigial scales whorled at nodes of jointed stems ....*Equisetum,* G 51; BB 39
    4. Leaves very long and narrow, 3-20 by 0.5-1.0 cm, very closely imbricated on short corm-like stem.................... *Isoetes,* G 58; BB 50
    4. Leaves small, 2-10 mm long, very closely imbricated...... 5
    4. Leaves larger, broader, frond-like, common true ferns.... 6

5. Homosporous, *i. e.*, spores of one type only........ *Lycopodium*, G 54; BB 43

5. Heterosporous, *i. e.*, spores of two types in regard to size........ *Selaginella*, G 57; BB 48

  6. Fertile and vegetative fronds entirely separate and conspicuously unlike each other........ 7

  6. Not differentiated into separate vegetative and fertile fronds, or if so they are not conspicuously different from each other........ 10

7. Stipe of fertile frond clothed with dense brown tomentum. Vegetative fronds may be similar in this regard........ *Osmunda cinnamomea*, G 47; BB 7

7. Stipe of fertile frond not as above........ 8

  8. Fertile frond bipinnate........ 9

  8. Fertile frond once-pinnate........ *Onoclea*, G 45; BB 11

9. Fertile frond 12.5-40 cm long. Fertile portion of more than five pinnate divisions........ *Onoclea*, G 45; BB 10

9. Fertile frond 5-12.5 cm long. Fertile portion of five closely crowded pinnate divisions........ *Schizaea*, G 45; BB 9

  10. Individual fronds composed of both entirely vegetative and entirely fertile pinnae........ 11

  10. Sori borne on the backs of the otherwise vegetative fronds........ 14

11. Vegetative segment of frond simple..*Ophioglossum*, G 47; BB 1

11. Vegetative segment of frond compound........ 12

  12. Fertile segment of frond distant, above the vegetative.. 13

  12. Fertile segments merely the contracted terminal portion of the ordinary frond........ *Polystichum*, G 40; BB 16

  12. Fertile pinnae 1-8, in the middle portion of the vegetative frond........ *Osmunda Claytoniana*, G 47; BB 8

13. Frond with fleshy stipe, ultimate divisions with toothed margins........ *Botrychium*, G 47; BB 3

13. Frond without fleshy stipe, ultimate divisions with entire margins........ *Osmunda regalis*, G 46; BB 7

  14. Sori not covered with an indusium; or the indusium may drop off when young........ 15

  14. Sori covered with an indusium. Forms in which indusium drops when young may be sought in either of these two characters........ 18

15. Fronds once-pinnatifid .... *Polypodium,* G 34; BB 35

15. Fronds twice-pinnatifid to 4-pinnate, green on both surfaces.... 16

15. Fronds 1-4 pinnate, lower surface hairy, tomentose, or covered with a white or waxy powder............ *Notholaena,* G 35; BB 35

16. Rachis winged between the pinnae............ *Phegopteris,* G 35; BB 23

16. Rachis not winged between pinnae............ 17

17. Stipes, rachis and ventral side of midvein minutely chaffy............ *Woodsia,* G 43; BB 11

17. Stipes, rachis and ventral side of midvein without chaff............ *Cystopteris,* G 43; BB 14

18. Indusium false, *i. e.,* formed from the revolute margin of the frond............ 19

18. Indusium true, *i. e.,* not formed from the revolute margin of the frond............ 24

19. Sori forming a more or less continuous marginal band............ 20

19. Sori not forming a more or less continuous marginal band........ 23

20. Stipe and rachis blackish or purplish............ 21

20. Stipe and rachis chestnut-brown............ *Cheilanthes,* G 36; BB 33

20. Stipe straw-colored or greenish............ 22

21. Stipe and rachis smooth and shining, without scales............ *Notholaena,* G 35; BB 35

21. Stipe and rachis clothed with brownish scales............ 21a .... ~~*Cheilanthes,* G~~ 36; BB 33

22. Fronds not dimorphic, stipe and rachis smooth or densely chaffy throughout; pinnules glabrous or slightly pubescent on ventral surface near margins and midvein .... *Pteris,* G 36; BB 31

22. Fronds dimorphic, fertile narrower than sterile, chaff limited to base of stipe, pinnules glabrous............ *Cryptogramma,* G 36; BB 52

23. Sori small, globular, at the apex of free veins, appearing as if raised upon a pedestal .... *Dicksonia,* G 44; BB 14

23. Sori oblong or somewhat crescent-shaped............ *Adiantum,* G 35; BB 31

24. Fronds transparent, consisting of a single layer of cells only .... *Trichomanes,* G 33; BB 8

24. Fronds thicker, of more than one layer of cells............ 25

21a. Upper surface of pinnules enti
glabrous or with occasional sc
on back of midvein...Pellaea G
BB 33
21a. Upper surface of pinnules dens
tomentose or with numerous sca
not limited to back of midvein
Cheilanthes G 36; BB 33

25. Sori more or less elongated, straight or curved........................ 26
25. Sori more or less rounded 29
25. Sori rounded when young, but confluent when old.. *Polystichum,* G 40; BB 16
26. Veins reticulated 27
26. Veins free 28
27. Sori forming a chain-like row on either side of midvein.. *Woodwardia,* G 37; BB 34
27. Sori scattered, some parallel with midvein and some parallel with lateral veins..............................*Camptosorus,* G 40; BB 25
28. Sori single, frond once-pinnatifid to 4-pinnate.. *Asplenium,* G 38; BB 26
28. Sori confluent in pairs, frond entire or merely undulate ....*Scolopendrium,* G 40; BB 25
29. Indusium attached by the center.. 30
29. Indusium attached by one side..........*Cystopteris,* G 43; BB 14
29. Indusium inferior, *i. e.,* attached at two or more points beneath the sporangia 31
30. Indusium round, without a sinus.. *Polystichum,* G 40; BB 16
30. Indusium round or reniform, with a sinus .... *Aspidium,* G 41; BB 17
31. Indusium two-valved, cup-shaped........*Dicksonia,* G 44; BB 14
31. Indusium with more than two valves......*Woodsia,* G 43; BB 11

CHECK-LIST OF INDIANA FERNS AND FERN ALLIES

The following sixty-five species of ferns and fern allies are to be found growing out of cultivation in Indiana:

Adiantum pedatum L.
Aspidium cristatum Sw.
A. Goldianum Hook.
A. marginale Sw.
A. noveboracense (L) Sw.
A. spinulosum (Mueller) Sw.
A. spinulosum intermedium (Muhl.) Eaton.
A. Thelypteris (L) Sw.
Asplenium acrostichoides Sw.
A. angustifolium Michx.
A. ebenoides R. A. Scott.
A. Filix-femina (L) Bernh.
A. pinnatifidum Nutt.
A. platyneuron (L) Oakes.
A. Ruta-muraria L.
A. Trichomanes L.
Azolla caroliniana Willd.

Botrychium obliquum Muhl.
B. obliquum dissectum (Spreng) Clute.
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B. simplex E. Hitch. (Doubtful.)
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Cheilanthes lanosa (Michx.) Walt.
Cystopteris bulbifera (L) Bernh.
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E. hyemale intermedium A. A. Eaton.
E. laevigatum A. Br.
E. robustum A. Br.
E. variegatum Schleich.
Lycopodium clavatum L.
L. complanatum L.
L. inundatum L.
L. lucidulum Michx.
L. obscurum dendroideum (D. C. Eaton) Michx.
L. obscurum L.
L. porophilum (L. and U.) Clute.
L. selago L.
Marsilea quadrifolia L.
Onoclea sensibilis L.
O. Struthiopteris (L) Hoffm.
Ophioglossum vulgatum L.
Osmunda cinnamomea L.
O. cinnamomea frondosa Gray.
O. cinnamomea incisa J. W. Huntington.
O. Claytoniana L.
O. regalis L.
Pellaea atropurpurea (L) Link.
Phegopteris Dryopteris (L) Fee.
P. hexagonoptera (Michx.) Fee.
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P. vulgare L.
Pteris aquilina L.
Selaginella apus (L) Spreng.
S. rupestris (L) Spreng.
Woodsia obtusa (Spreng.) Torr.
Woodwardia virginica (L) Sw.